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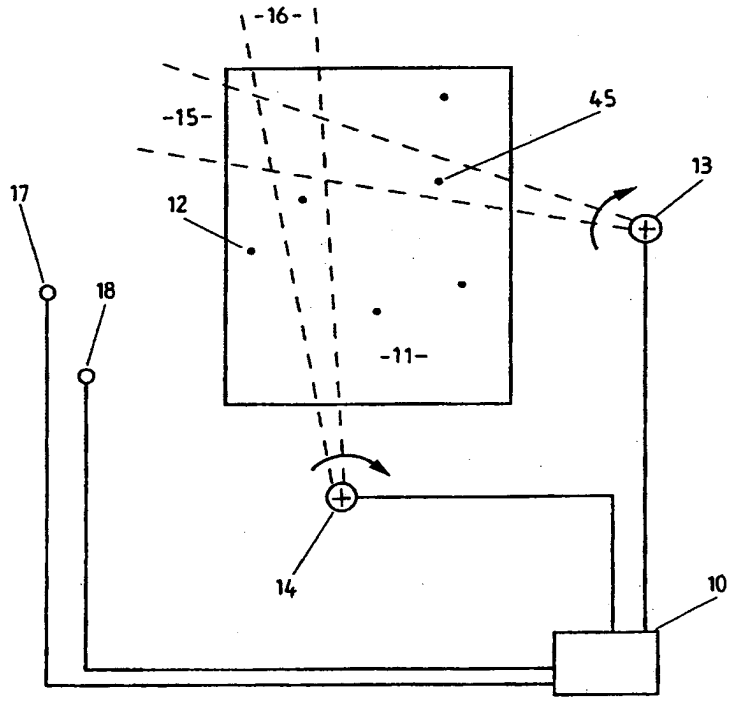
(54) Title: IMPROVEMENTS RELATING TO POSITION DETERMINATIONS

(57) Abstract

A signalling system for tracking players on a sports field or other objects in a wide range of circumstances. Scanning beams sweep over a region in which the players are active and sweep related information is simultaneously transmitted. Portable devices carried by the players detect each pass of the scanning beams and store relevant parts of the sweep related information for each beam. The information is transmitted by the devices to a central site where position calculations are carried out. Various embodiments have a range of methods for transmitting and receiving information to and from the portable devices. Position information may then be used for statistical analyses or graphical displays for example.



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IMPROVEMENTS RELATING TO POSITION DETERMINATIONS

FIELD OF THE INVENTION

This invention relates to systems which may be used when gathering position information, particularly but not solely the positions of a number of entities moving within a predetermined region, such as sports players on a game field or boats on a watercourse.

BACKGROUND TO THE INVENTION

The performance of sportsmen and women in the field is of interest for both training and sports broadcast purposes. Detailed information on the individual performances may be obtained from real time position determinations made continuously during the course of a sports match or training session. The position information can be used for graphical displays of the movements of team members around the sports area, or to calculate player statistics such as speed, energy expenditure and distance travelled, for example.

Various systems have been developed to enable position determinations and statistical analyses of this kind. Most involve triangulation of the player positions using signals generated by portable radio transmitter devices and detected at a number of receiver devices placed around the region in which the players move. The portable devices are generally embedded in the players clothing and must be reduced as far as possible in size, weight and power requirement . In some cases the position of a ball which may be used by the players is also determined. A description of some existing systems can be found in US 5,513,854 and WO 95/10337, for example.

Such systems might be used to track animate or inanimate objects in a wide range of environments. Applications include athletes competing individually in track, field or swimming events, horse racing, team sports such as football or basketball, and boat or car race competitions. Tracking of these entities is not necessarily limited to two dimensions, so that position determinations may also be made for players moving in three dimensions, such as during a ski race or underwater hockey match, for example.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide systems which enable position information to be gathered in real time without undue inconvenience to the entities involved, or at least to provide an alternative to existing systems.

In general terms, this object is achieved by providing a signalling system in which one or more beams scan the entities while information related to the scanning or sweeping action of the beams is also transmitted. The sweep related information may be provided either as part of each beam or as a separate simultaneous transmission, for example. Each entity carries a portable receiver/transmitter device which selects from the sweep related information at an appropriate instant and retransmits information either immediately, delayed or on interrogation, for processing at a central site. The various transmitter receiver systems which are required will typically operate at radio frequencies but beams involving visible or infrared laser light may be possible.

The entities may be people, animals or inanimate objects which generally move within a predetermined region either one at a time or simultaneously. The region might be one or more approximately one dimensional lanes on a running track, an approximately two dimensional playing area such as a football field, or a more general three dimensional space such as a ski field or a swimming pool, for example. Signalling systems according to the invention can be designed to cover a wide variety of regular and irregularly shaped regions.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will be described with respect to the drawings, of which:

Figure 1 schematically shows a two beam system by way of example of the first embodiment,

Figure 2 is a flowchart indicating computer controlled operation of the system in Figure 1,

Figure 3 schematically shows a portable radio receiver/transmitter device for the system,

Figures 4a, 4b indicate reception of two signals by the portable device,

Figure 5 is a flowchart indicating operation of the portable device,

Figure 6 shows a portable receiver/transmitter for use with a second embodiment related to the system shown in Figure 1,

Figure 7 schematically shows a third system representing a third embodiment also by way of example,

Figure 8 shows a typical transmitter system for the third embodiment,

Figure 9 shows a typical receiver system for the third embodiment, and

Figure 10 shows a portable receiver/transmitter for the third embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Signalling systems according to the invention are described generally in relation to players on a sports field although it will be appreciated that a wide range of other applications are also envisaged. Three preferred embodiments are described each involving operation of one or more scanning beams with transmission of sweep related information to portable devices which are carried by the players. Methods of processing the signals which are received from the portable devices is not described in detail but may involve any of various correlation techniques as will appreciated.

Figure 1 shows a system according to the first embodiment which might be used to track players on a rugby field, for example. The system is operated largely by a computer controller or processor 10 which is located in the vicinity of a playing region 11. A few players or other entities 12 are shown within this region in no particular number or arrangement. Two reference transmitters 13, 14 are placed on either side of the region and produce scanning beams 15, 16 which sweep the region as indicated by respective dashed lines and arrows. The transmitters are best placed on perpendicular sides of the region for optimum accuracy, although a variety of arrangements are possible. One, three or more reference transmitters may be used according to the particular activity taking place or the accuracy which is required, all generally though not necessarily, under continuous control of the computer 10. An interrogation transmitter 17 and an interrogation receiver 18 are also located in the vicinity of the playing region to request and receive information from a plurality of portable receiver/transmitter devices which are carried by each of the players. The transmission characteristics of the interrogation and player devices are generally omnidirectional and the player devices generally transmit on the same carrier frequency.

The computer controller 10 may take many forms but will generally be a personal computer arrangement operated by a television commentator and a number of technical assistants. It may be located in a permanent booth at the site of a sports match or other event where the positioning system is used, or in an operations vehicle which is temporarily at the site. The system calculates player statistics based on real time position information derived by interrogation of the portable player units as will be described below. The position information may be presented immediately in graphical form on a video screen to become part of a television broadcast, for example, and may be recorded for later analysis by the players and coaches. In some cases the information may assist referees with interpretation of an event and whether or not to award a penalty or a victory or some other appropriate result in the circumstances. Statistics such as speed and

distance travelled by the players may also be calculated from the position information and made available to the operator for live commentary, or to others for later analysis.

The scanning beams 15, 16 which originate at reference transmitters 13, 14 may be generated in various ways, such as by steerable phase arrays or physically rotating antennae, neither of which need be described in detail. Radio frequency carriers are preferably used in the present embodiment. Each beam is narrowly confined to horizontal and vertical angles of approximately 1° and 5° respectively, or better, and shaped to form a fan which sweeps over region 11 from each transmitter. The sweep rates are preferably about 50 Hz and may be based on various patterns such as an oscillation back and forth through 180° or a full rotation of 360° about the transmitters, for example. Other more complex patterns involve an intermittent long sweep followed by a number of short sweeps over particular parts of region 11. Each beam contains a signal with sweep related information including the instantaneous sweep angle of the transmitter from a predetermined reference orientation. The signals are preferably broadcast on different radio or microwave frequency carriers but may employ the same carrier frequency if the transmitters are swept alternately over area 11. The rate and accuracy of position measurements which are required for each particular use of the system will determine which beam characteristics are useful in the circumstances.

Figure 2 is flowchart indicating generally how the system of Figure 1 functions under control of the computer processor 10. The system is first set up by a human operator at a particular venue such as a race track or sports field, and may be temporarily or permanently installed. In step 20 the operator initialises the system by determining the positions of reference transmitters 13, 14 with respect to the playing region 11, and a base orientation for the angular sweep of their beams. The operator then turns on the interrogation devices 17 and 18 in step 21, and in step 22 transmits an identification code to each of the receiver/transmitter units which will be carried by the players. Alternatively the identification codes may be permanently stored in each player device and simply retrieved from the devices at this stage. A list of player names and other information is generally input or loaded from another source and linked to the identification codes. A repetitive routine in which the unit positions are determined and output in a required format is then initiated and continues to run until the system shut down at the end of the event.

Consecutive sweeps of the reference transmitters 13, 14 are triggered in step 23, although these devices could be activated in some other automatic fashion without necessarily being continuously controlled by the computer 10. Consecutive polls of the player

devices by way of the interrogation transmitter 17 and receiver 18 are coordinated with the sweeps in step 24, so that information is extracted from the player devices in an efficient manner. Interrogation of the devices produces a measurement of the most recent position for each player in terms of two angular measurements or bearings from the two known positions of the reference transmitters. In step 25 the intersection of two hypothetical lines to the player from each of the two reference transmitters is then used to determine the player position in a local coordinate system. Finally the current player positions are output or stored in a required form, preferably plotted as part of a graphical display of the players movements within region 11.

Figure 3 is a schematic diagram showing functional elements of a portable receiver transmitter device which may be used in a signalling system as described above. The device is manufactured to be as small, lightweight and robust as possible, so as to be conveniently embedded in some part of each players clothing such as a collar, cap or boot, or otherwise carried by each entity for which a position is to be determined. The device contains receive and transmit antennae 30, 31 which will generally be the same component. Antenna 30 is connected to one or more receiver units 32 respectively tuned to the carrier frequency of signals transmitted by each of the reference transmitters 13 and 14 shown in Figure 1. Only one such receiver unit is required where the reference transmitters operate on the same frequency while three would be required to receive from three transmitters with different frequencies, and so on, depending on the requirements of a particular system. Receiver unit 33 is tuned to the frequency of interrogation transmitter 17. Each of the receivers 32 produces output for a respective signal level detector 33, a data detector 34 and ultimately a buffer 35 whose functions will be described in relation to Figures 4a, 4b and 5. The buffers are connected to a data gate 36 which passes information from the buffers to a transmitter unit 37 and antenna 31. Receiver unit 33 for the interrogation signal from transmitter 17 is connected to a data detector 38 and identification match detector 39. The match detector is in turn connected to data gate 36 and is connected to enable or disable the transmitter 37. These functional elements may be implemented as part of a software routine in a microprocessor.

Figures 4a and 4b indicate schematically how signals from the reference transmitters 13, 14 may be received at one of the portable player devices such as shown in Figure 3. In this case two reference signals 40 have been indicated by way of example, as might be received over a brief period of time at a device carried by player 45 in Figure 1. Each reference signal contains sweep related information 41, preferably a measure of the angle of the respective beam from a known orientation. Timing data or a simple count value might also be used. Angular differences of approximately one degree as shown, should

be sufficiently precise for most purposes, although finer or coarser information content may be imparted to the signals if required. The player device holds a threshold 42 for each reference signal, typically a voltage level appropriate for the output of the receiver units 32, below which the signal is ignored and above which information contained in the signal is stored in buffers 35.

In Figure 4a beam 15 from transmitter 13 approaches and sweeps across the player at angles between about 25 and 35 degrees with the signal strength crossing the threshold for angles of 29 and 30 degrees. In Figure 4b beam 16 from transmitter 14 subsequently approaches and sweeps across the player with signal strength being above the threshold for angles of approximately 69 to 71 degrees. An average of the stored angle information is then used as the required bearing between transmitter and player in each case. Other methods of determining the bearings may of course be employed, such as an estimation of peak strength or rate of change.

Figure 5 is a flowchart broadly outlining the operation of a player device such as described in relation to Figures 4a and 4b. The device is first initialised in step 50 during set up of the system overall in Figure 2, by input or retrieval of an identification code. Reference signal thresholds may also be input in conjunction with an adjustment of the power levels of the reference transmitters. The device then cycles through a routine in which reference and interrogation signals are repeatedly detected and processed until the system is shut down. In step 51 the device waits for or is interrupted by a beam from a reference transmitter. The strength of the signal is assessed and beam angle information is stored when appropriate in steps 52 and 53, as described above. In step 54 the device is interrupted by a beam from the other or another reference transmitter (depending on the number of such transmitters in use) and information is stored in steps 55 and 56. In step 57 the device receives a request from the interrogation transmitter to transmit the most recently stored information to the interrogation receiver. If the request contains the identification code for the device then transmission takes place otherwise the request is ignored in step 58. Alternatively the device may automatically transmit the information following each sweep of the reference beams although a process of this kind is error prone when all of the player devices transmit on the same frequency. Transmission takes place in steps 59 and 60 as a packet of data containing the identification code and the stored information from which the player position is calculated.

Referring again to Figure 1, an alternative embodiment with potentially higher accuracy in determination of player positions is also possible. In general terms, the sweep related information which was incorporated in the scanning beams 15 and 16 may be provided

separately by an omnidirectional transmitter, as an additional function of the interrogation transmitter 17, for example. This allows the scanning beams to be narrowed in width and potentially generated at visible or infrared laser frequencies. The scanning beams are preferably swept alternately from the reference transmitters 13 and 14 at a common frequency, each accompanied by a synchronised transmission of their respective sweep related information from the transmitter 17. After each sweep of the scanning beams, the transmitter 17 carries out an interrogation of the player devices and information is transmitted by the devices to the receiver 18. Operation is coordinated by the computer 10.

Figure 6 is a schematic diagram showing functional elements of a portable receiver/transmitter device which may be used in the alternative system described in relation to Figure 1. Receive and transmit antennae 60 and 61 are generally the same component. Antenna 60 is connected to a detector 62 which is tuned to the frequency of the scanning beams 15 and 16. A receiver unit 63 is tuned to the interrogation transmitter 17 and now carries out two functions as mentioned above. Two buffers 64 which correspond to the number of scanning beams are each connected to both detector 62 and receiver 63. On recognition that the device is under one or other of the scanning beams, an appropriate buffer is selected by the detector 62 and used to store the most recent sweep information held by receiver 63. This represents the angular position of beam 15 about reference transmitter 13 for example. Both buffers are filled and the transmitter carries out interrogation by sending out a sequence of device identification codes as described above. Each code is passed by receiver 63 to a match detector 69 which in turn enables or disables a transmitter unit 67 through gate 66.

Figure 7 indicates a signalling system according to a third embodiment of the invention, set up in a different environment to that of Figure 1. In this example the system covers an irregular region 71 such as a motorcycle track, skifield or watercourse for example. The system is operated by a computer controller 70 which may be linked to a number of transmitter/receiver base stations 72, 73, 74 and possibly more, by either wired or wireless connections. Each station produces a scanning beam such as beams 75 and 76 indicated by dashed lines and arrows. Stations may be placed as required to cover the region in two or three dimensions, with their beams suitably shaped for scanning a vertical dimension. Different transmitters may also cover different parts of a large region, and may be placed inside the region with a full circular sweep in some cases.

Each station in Figure 7 carries out both transmit and receive functions so avoiding the need for additional equipment such as the interrogation transmitter and receiver described

in relation to Figure 1. The functions are generally carried out simultaneously through a common antenna at each station as described below. Information related to the sweep of each beam is modulated on the beam so that separate transmitters such as the interrogation transmitter 17 are not required. A number of players, vehicles or other objects 79 are shown the region 70 each carrying a receiver/transmitter device which is able to interact with the fixed stations.

Figure 8 is a schematic diagram showing transmitter components of a station such as shown in Figure 7. Each station includes an directional antenna 80 which produces a generally fan shaped scanning beam 87 as indicated from above. The width of the fan will depend on the horizontal or vertical extent of the region in which the players are able to move. An scan generator 82 and RF generator 83 are operated by a computer controller 84 and coupled to the antenna by an isolator 81. The controller is programmed with a particular beam shape and sweep pattern as required for a particular event. The beam generated by the transmitter incorporates sweep related information as determined by the controller, such as angular displacement or transit time of the beam from a reference orientation.

Figure 9 shows receiver components of a station as mentioned in Figure 8. The receiver is coupled to antenna 80 through isolator 81 shared with the transmitter. A filter 90, amplifier 91 and demodulator 92 form the input stages in a typical receiving system. There will generally be a series of decoder functions 93 corresponding to the number N of portable devices carried by players in the field. Each player device preferably transmits a signal on a unique frequency or which is otherwise unique to the player through an identification code, and the respective signals are decoded for a common processor stage 95.

Figure 10 shows a simple portable device for use in a signalling system as described in relation to Figure 7. The device is designed for minimal cost, weight and power consumption, and may be disposable in some systems. Each device includes an antenna 100 for both reception and transmission of signals through a simple switch 101. A receiver 102 receives incoming beam energy and sweep information from each station and the information is immediately retransmitted. A frequency shift encoder 103 shifts the incoming frequency by a small amount unique to each device. A player code stored in a memory element 104 determines the frequency shift. The device is powered by a battery, solar cell or similar source 105.

Signalling systems according to the invention may be constructed in a variety of forms for a variety of purposes within the scope of the following claims. The embodiments described above are given by way of example only.

CLAIMS:

1. A signalling system for use in determining position information for a plurality of entities within a region, comprising:

a transmitter system which sweeps at least one scanning beam over the region and simultaneously transmits sweep related information,

a plurality of portable receiver/transmitters for location on the entities to detect the beam and receive the sweep related information, and transmit respective signals containing or derived from the information, and

a receiver system which receives the signals transmitted by the portable receiver/transmitters and produces output containing information related to the respective entities.

2. A system according to claim 1 wherein:

the transmitter system sweeps two or more scanning beams in an approximately common plane from different sides or parts of the region.

3. A system according to claim 1 wherein:

the transmitter system generates and sweeps a scanning beam over the region in a substantially vertical direction.

4. A system according to claim 1 wherein:

the transmitter system incorporates sweep related information respectively in each scanning beam.

5.. A system according to claim 1 wherein:

the transmitter system incorporates sweep related information for each beam in one or more omnidirectional signals.

6. A system according to claim 1 wherein:

the receiver system includes an interrogation transmitter which transmits transmission request signals to the portable receiver/transmitters.

7. A system according to claim 1 wherein:

the sweep related information includes angular data or timing data according to beam orientation about a reference point.

8. A position determining system comprising:

a signalling system according to claim 1, and

a signal processor which analyses output from the receiver system and determines the positions of the entities.

9. A method of signalling for use in determining position information for entities within a region, comprising:

sweeping at least one scanning beam over the region and transmitting sweep related information,

detecting the beam and receiving sweep related information at one or more portable devices carried by respective entities,

transmitting signals containing sweep related information or derived information from each of the portable devices, and

receiving the signals from the portable devices to produce output containing information related to the respective objects.

10. A method according to claim 9 further comprising:

incorporating respective sweep related information in each beam.

11. A method according to claim 9 further comprising:

transmitting sweep related information for each beam in one or more omnidirectional signals.

12. A method according to claim 9 further comprising:

transmitting information from the portable receiver/transmitters on interrogation by the transmitter system.

13. A method according to claim 9 further comprising:

transmitting identification information from the portable devices with the sweep related information.

14. A method according to claim 9 further comprising:

sweeping two or more scanning beams over the region simultaneously at different frequencies.

15. A method according to claim 9 further comprising:

sweeping two or more scanning beams over the region alternately at a common frequency.

16. A method according to claim 9 further comprising:
receiving sweep related information from a beam at a portable device, and
transmitting the information from the device at a different frequency.

17. A portable device for use in a signalling system, comprising:
receiver means which detects one or more scanning beams transmitted by the signalling system and receives respective sweep related information, and
transmitter means which transmits the sweep related information or derived information to the signalling system.

18. A device according to claim 17 wherein:
the transmitter means includes a frequency shift encoder which stores sweep related information from a beam at one frequency and transmits the information at a different frequency.

19. A device according to claim 17 wherein:
the receiver means includes a beam detector and a receiver of sweep related information transmitted in a substantially omnidirectional signal.

20. A device according to claim 17 further including:
processing means which detects when the device is in the path of a beam and stores respective sweep related information for the beam.

21. A device according to claim 17 further including:
processing means which detects an interrogation signal from the signalling system and transmits the sweep related information only when identified by the interrogation signal.

22. A device according to claim 17 further including:
storage means for an identification code which is incorporated with the sweep related information by the transmitter means.

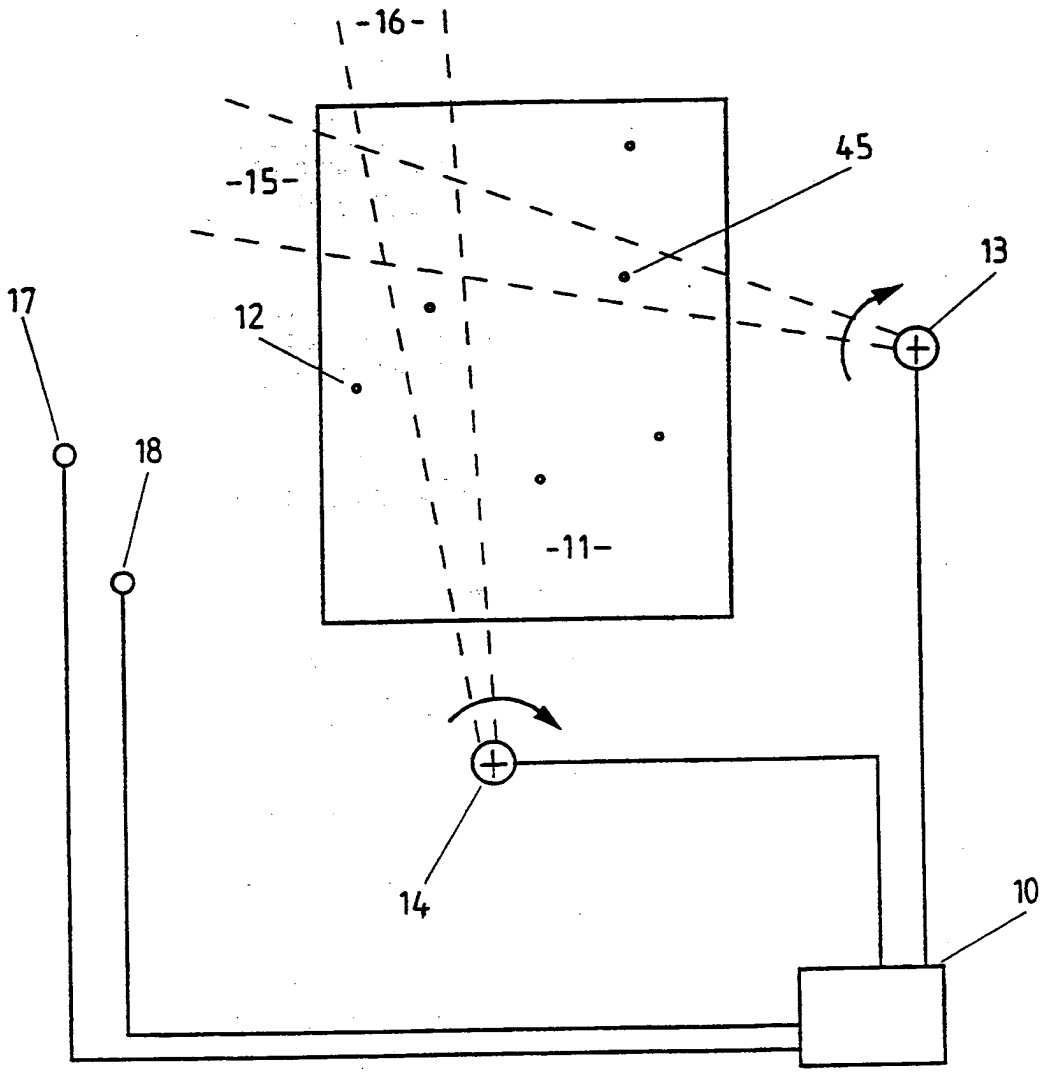


FIG. 1

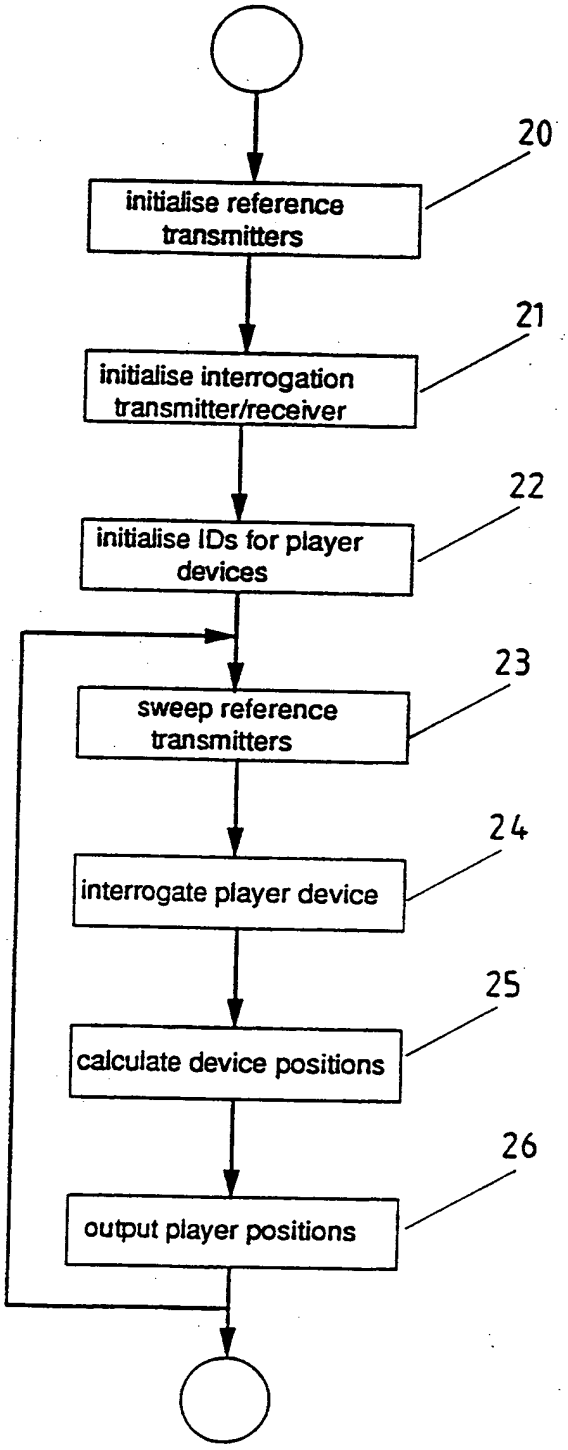


FIG. 2

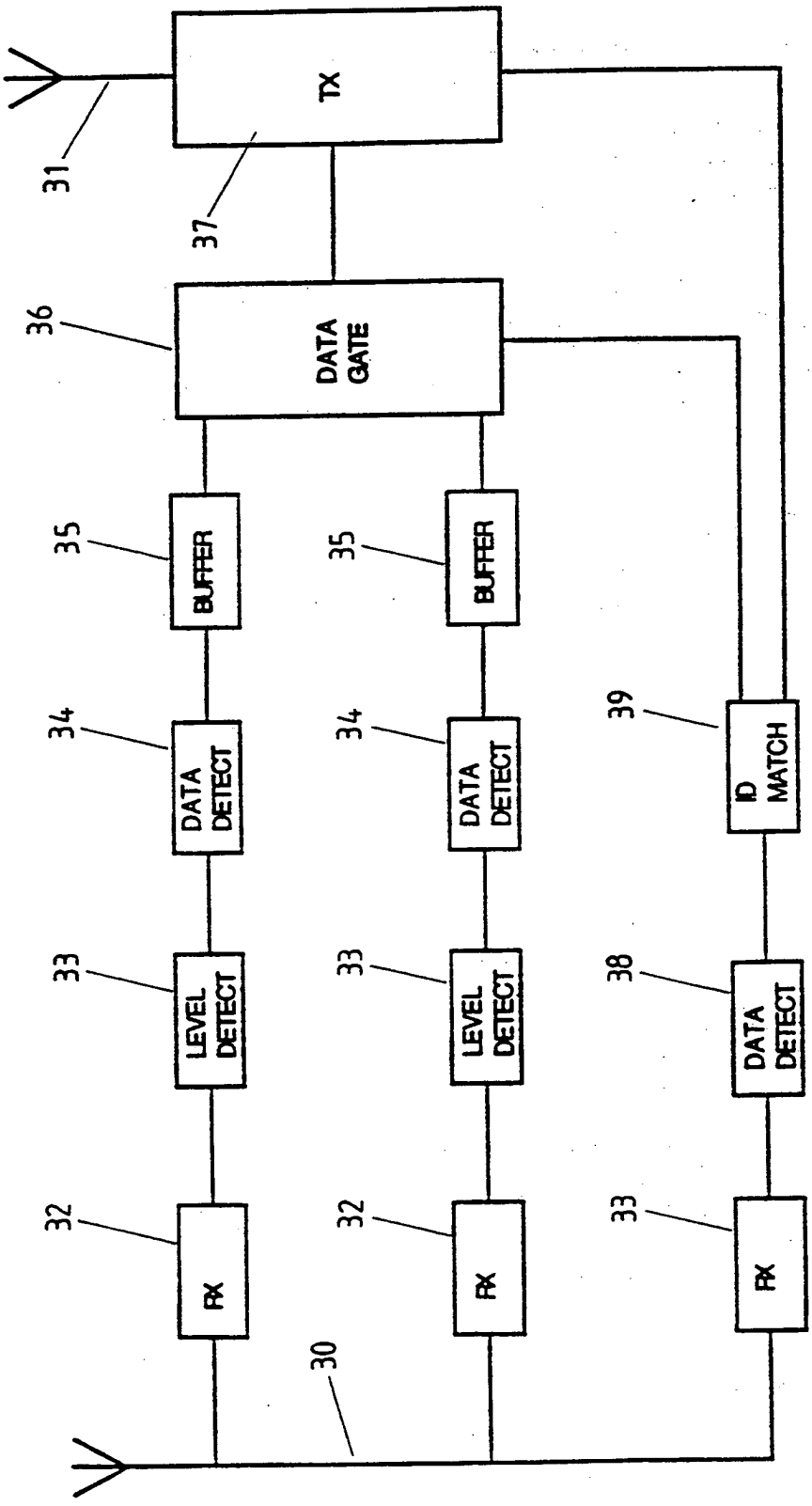


FIG. 3

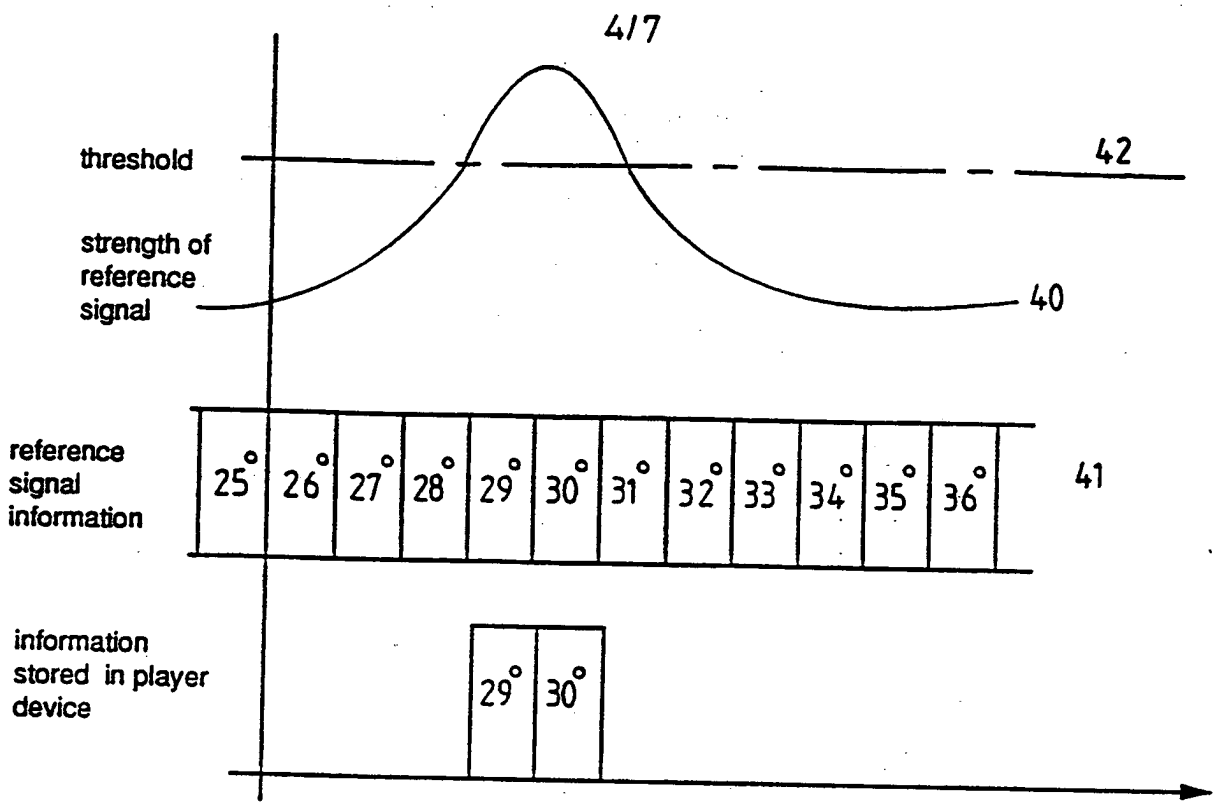


FIG. 4a

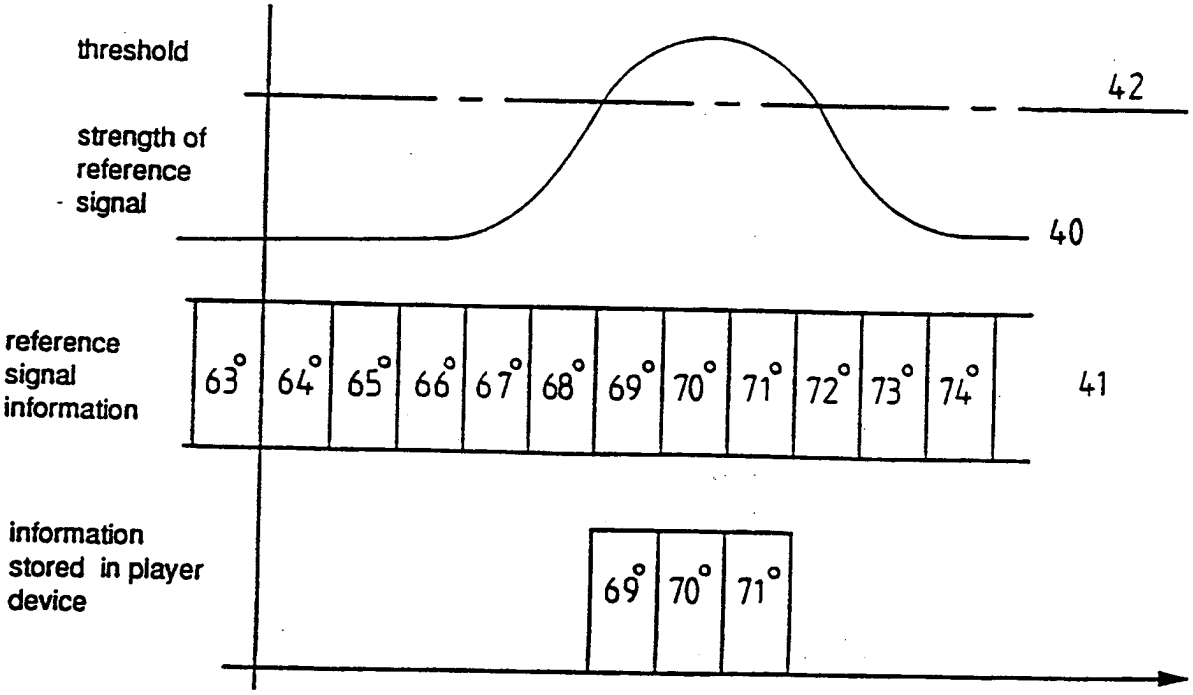


FIG. 4b

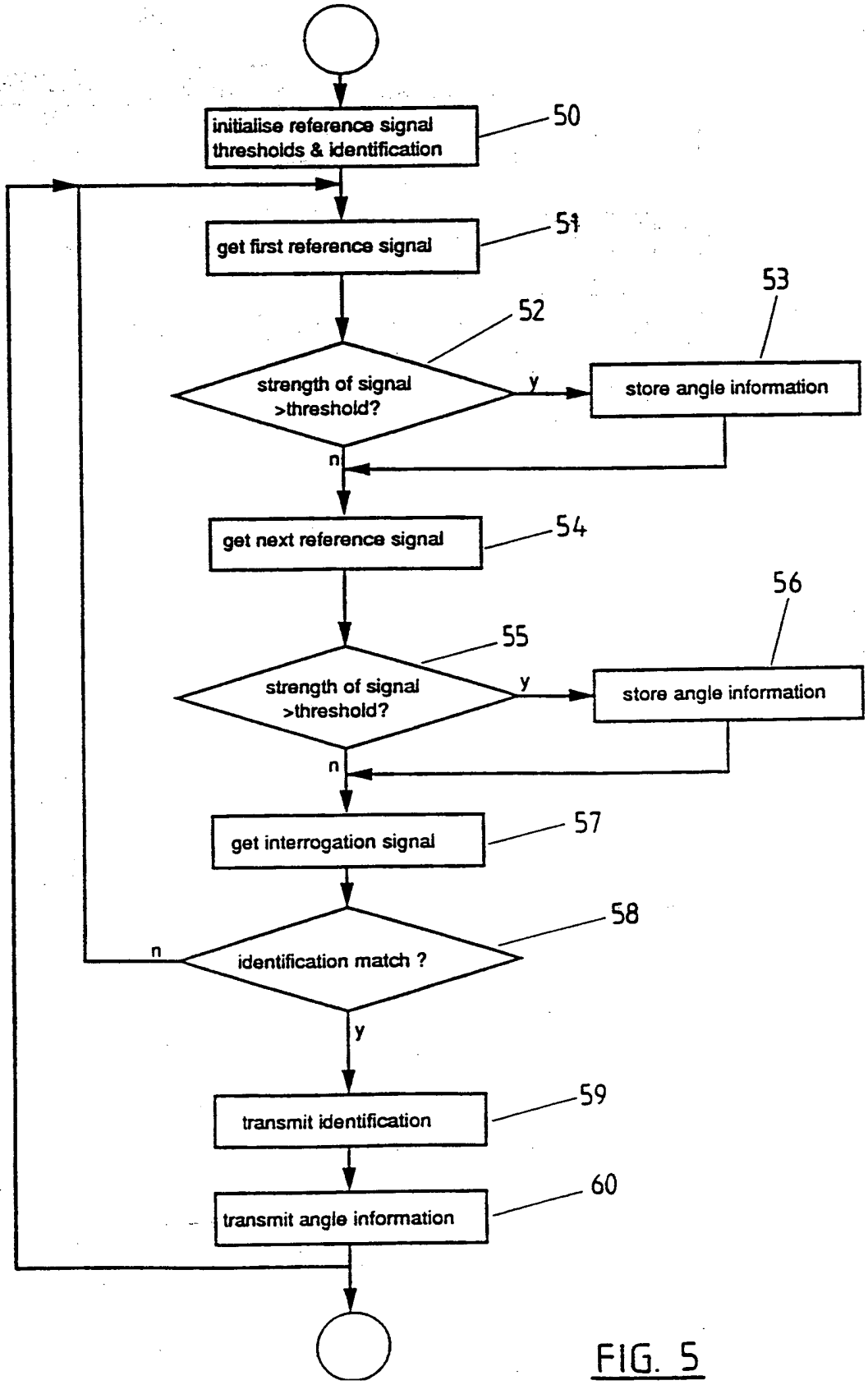


FIG. 5

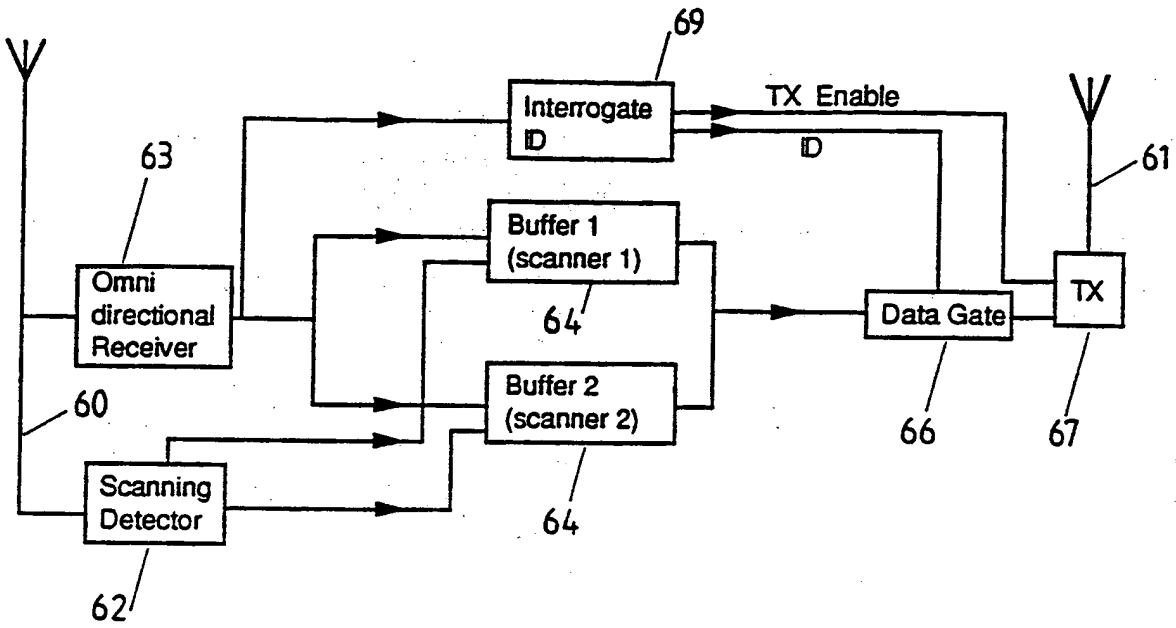


FIG. 6

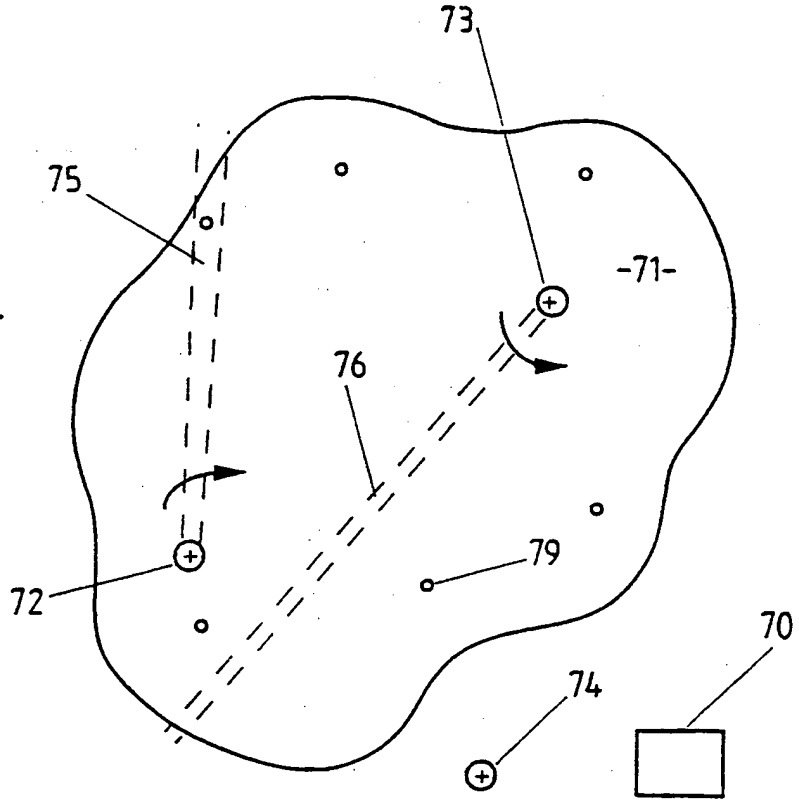


FIG. 7

FIG. 8

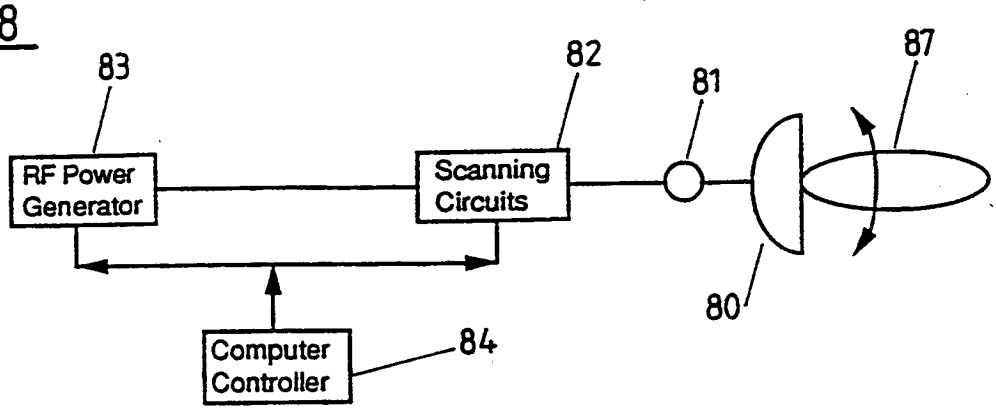


FIG. 9

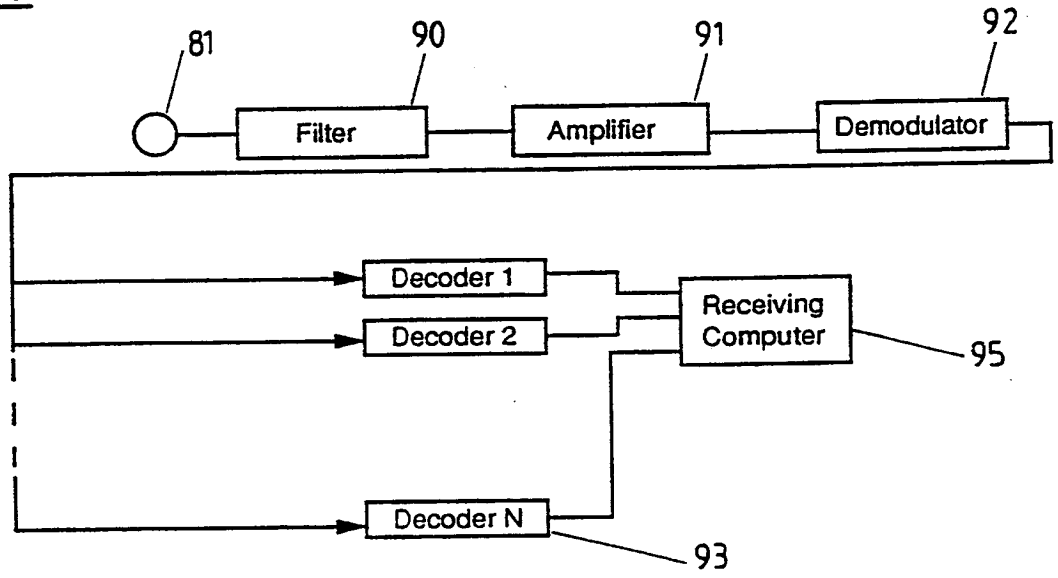
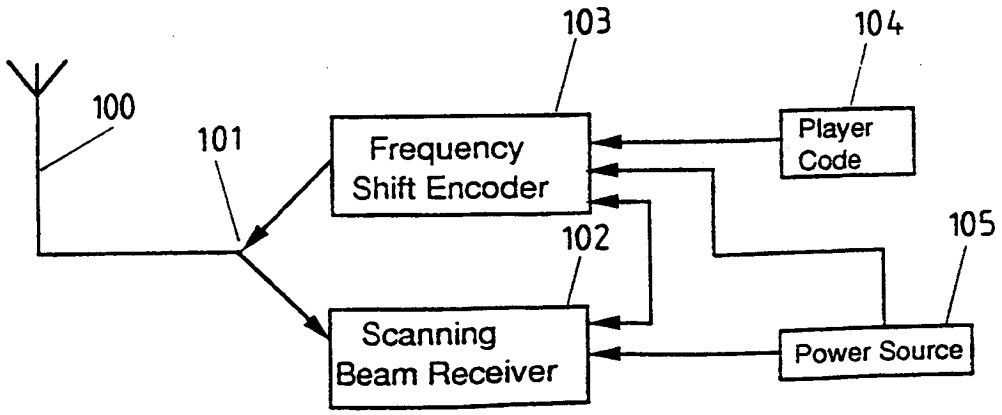


FIG. 10



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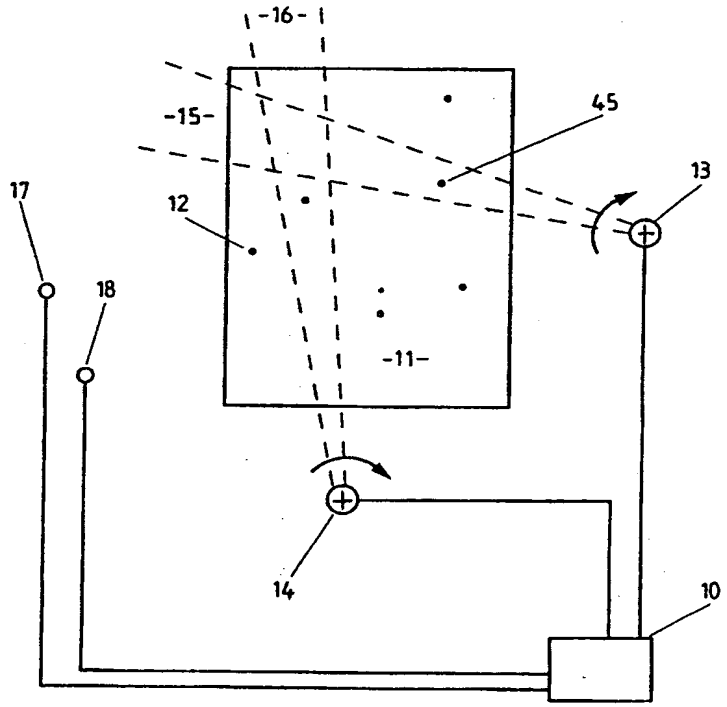
(57) Abstract

A signalling system for tracking players on a sports field or other objects in a wide range of circumstances. Scanning beams sweep over a region in which the players are active and sweep related information is simultaneously transmitted. Portable devices carried by the players detect each pass of the scanning beams and store relevant parts of the sweep related information for each beam. The information is transmitted by the devices to a central site where position calculations are carried out. Various embodiments have a range of methods for transmitting and receiving information to and from the portable devices. Position information may then be used for statistical analyses or graphical displays for example.



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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

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IPC 6 G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GLASGOW J A: "A scanning-beam microwave landing system incorporating Doppler coding" GEC JOURNAL OF SCIENCE & TECHNOLOGY, 1978, UK, vol. 44, no. 2, pages 87-92, XP002104082 ISSN 0022-4421 see page 90, right-hand column ---	1,9,17
A	PATENT ABSTRACTS OF JAPAN vol. 005, no. 182 (P-090), 20 November 1981 & JP 56 110064 A (TSUMURA TOSHIHIRO), 1 September 1981 see abstract ---	1,9,17

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Date of the actual completion of the international search	Date of mailing of the international search report
28 May 1999	25/06/1999

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A	GB 2 082 416 A (TSUMURA TOSHIHIRO) 3 March 1982 see abstract -----	1

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Information on patent family members

Inter onal Application No
PCT/NZ 98/00194

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2082416 A	03-03-1982	NONE	